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Lead-Acid Battery

Foreword

Most of the technology we use today in the Bell System has been developed since the invention of the telephone just less than a century ago. Our basic source of stand-by power, however, is still the lead-acid secondary cell, which was invented by Planté in 1859, and which, apart from the introduction by Fauré of pasted electrodes a little later, remains essentially unchanged in design to the present day. The files of the U. S. Patent Office are crammed with disclosures of other secondary cells, and some of these have achieved a limited market; but for most of our business, as for the automotive industry, the lead-acid cell still reigns supreme. The reasons for this are, of course, partly technical and partly economic. The lead-acid cell has an energy density figure that still looks reasonably good when compared with that of its competitors; it can be cycled many times without irreparable damage; the internal resistance is low; and it can be maintained fully charged for long periods by passing through it a small "float" current. At the same time, despite the somewhat limited use of mass production techniques, battery manufacturers have been able to produce cells and sell them to us at a price that compares favorably with the price of other secondary cells.

Nevertheless, the experience of the Bell System with lead-acid secondary cells has not been free from difficulty. The nature of our business places special demands on the performance of a secondary

cell and calls for a design different in important respects from that appropriate to a secondary cell for automotive use. Of course, the cells we buy from the various battery manufacturers are built to designs evolved by them with standby power service in mind. Nevertheless, there have been problems in the field. Maintenance costs have typically been higher and battery life shorter than one might reasonably expect.

Over the years, Bell Laboratories scientists and engineers have worked with the battery manufacturers to assist them in improving their designs. By the early sixties, however, it was clear that the performance of cells in the Bell System was still very far from satisfactory, and there began in fact to be clear indication that efforts to patch up the technology on one front had led to more serious difficulties on others.

In 1964 it was decided, therefore, that a look should be taken at the lead-acid design problem as a whole. This task, which began under F. J. Biondi in the Electronic Components Development Area, and has since expanded to include contributions from a number of other parts of Bell Laboratories and of the Western Electric Company, is now approaching completion. From this work has resulted a new design for the lead-acid cell, which, while retaining unchanged the basic electrochemical principles of the device, incorporates a number of important new design features.

Cells of the new design have been made in experimental numbers at the Nassau Smelting and Refining Company, a Western Electric subsidiary, in Tottenville, Staten Island, New York. This operation has allowed us to work with prototype production machinery under something approximating realistic factory conditions. It is our hope and expectation, however, that we shall find outside vendors interested in manufacturing cells according to the new design for sale to the Bell System.

While realistic life-tests of cells made according to the new design are as yet, of course, in a very early stage, predictions of life expectancy can be made with reasonable assurance on the basis of an understanding of failure modes and a program of accelerated aging. As a result of this work we could, in fact, have designed a cell that would have a predicted life inappropriately long for Bell System purposes, acquired, of course, at an inappropriately high cost. We have therefore picked, on the basis of some necessarily crude economic estimates, a figure of 30 years for the minimum projected life and aimed the design at that figure.

The series of papers that follow describes the technical aspects of

this development. The paper by D. E. Koontz, D. O. Feder, L. D. Bahusci and H. J. Luer outlines the use of lead-acid cells in the Bell System and the difficulties experienced with the existing cells, and describes the new design. This paper makes clear that the principal problem with the existing design is the growth in size, with time on float, of the lead-calcium alloy positive grids. The following paper, by A. G. Cannone, Feder and R. V. Biagetti, shows how the grid growth problem has been substantially helped by the use of pure lead, and then still further reduced by designing the shape of the grid to obviate local buckling.

The third paper, by Biagetti and M. C. Weeks, describes the results of experiments with pure tetrabasic lead sulphate as the positive plate paste material instead of the proprietary mixture customarily used. Tetrabasic lead sulphate is shown to be less prone to shrinkage from the grid, because the lead dioxide crystals produced on forming tend to exist as a dense tangle of relatively large crystallites. The next paper, by P. C. Milner, summarizes what is known of the float characteristics of lead-acid cells, setting up a quantitative framework within which the float behavior of any lead-acid cell may be described by quoting a relatively small number of experimentally determinable parameters. T. D. O'Sullivan, Biagetti and Weeks next present the results of a series of electrochemical measurements on the new cell. They describe *inter alia* the float behavior and relate their results to Milner's analysis. They then go on to give the results of field tests on early models of the new cell. The sixth paper, by T. W. Huseby, J. T. Ryan and P. Huh-hauer, describes the work leading to the design of the jar and cover for the new cell. During the course of this work it was found that particular attention must be given to the presence of trace amounts of certain impurities, either in the stabilizer for the Polyvinyl Chloride or as solvents that may be introduced in certain ways of sealing the cover to the jar.

The electrochemical activity of these trace impurities is reported in the succeeding paper by A. D. Butherus, W. S. Lindenherger and F. J. Vaccaro, who quote maximum tolerable limits for a number of the impurities likely to be present. The sealing of the cover to the jar is discussed in the paper by D. W. Dahringer and J. R. Shroff, who developed a heat-sealing technique that is mechanically sounder than a solvent seal and also avoids the introduction of excessive amounts of electrochemically active impurities.

The next paper, by L. H. Sharpe, Shroff and Vaccaro, describes the solution of the post seal problem, in which, by means of a flexible

bellows, the post is given some freedom to move relative to the cover without stressing the seal. The tenth paper, by R. H. Cushman, describes a new technique for joining together the positive plates at their peripheries, using a continuous fusion bonding effected by an electrically heated tip. The final paper in this series, by Luer, indicates how cells of the new design can be incorporated into telephone plant to replace the present rectangular cells without the need for extensive redesign of the space set aside for accommodation of cells.

One word on terminology. To an electrochemist, a single jar containing two electrodes is a cell, and a number of these connected together in series constitutes a battery. In the Bell System we tend to refer to a single cell as a *battery*; a number of cells connected together is often called a *string*. Rather than attempt to impose on this set of papers a uniform terminology, I have left usage in this regard to the individual authors to decide. I trust, therefore, that electrochemists will be forgiving if they frequently find a cell called a battery, and power engineers similarly tolerant if they sometimes find a battery called a cell.

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